Species at Risk Act
Management Plan Series

Management Plan for the Wavyrayed Lampmussel (*Lampsilis fasciola*) in Canada

Wavyrayed Lampmussel

2018

Canada

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Preface

The federal, provincial, and territorial government signatories under the Accord for the Protection of Species at Risk (1996) agreed to establish complementary legislation and programs that provide for effective protection of species at risk throughout Canada. Under the *Species at Risk Act* (S.C. 2002, c.29) (SARA), the federal competent ministers are responsible for the preparation of management plans for species listed as special concern. They are also required to report on progress five years after the publication of the final document on the Species at Risk Public Registry.

The Minister of Fisheries and Oceans is the competent minister under SARA for the Wavyrayed Lampmussel and has prepared this Management Plan as per section 65 of SARA. In preparing this Management Plan, the competent minister has considered, as per Section 38 of SARA, the commitment of the Government of Canada to conserving biological diversity and to the principle that, if there are threats of serious or irreversible damage to the listed species, cost-effective measures to prevent the reduction or loss of the species should not be postponed for a lack of full scientific certainty. To the extent possible, this Management Plan has been prepared in cooperation with many individuals, organizations and government agencies, including the province of Ontario as per section 66(1) of SARA.

As stated in the preamble to SARA, success in the conservation of this species depends on the commitment and cooperation of many different constituencies that will be involved in implementing the directions and measures set out in this Management Plan and will not be achieved by Fisheries and Oceans Canada or any other jurisdiction alone. The cost of conserving species at risk is shared amongst different constituencies. All Canadians are invited to join in supporting and implementing this Management Plan for the benefit of the Wavyrayed Lampmussel and Canadian society as a whole.

Under SARA, a management plan provides the detailed recovery planning that supports the strategic direction set out in the document. The plan outlines conservation measures to be taken by Fisheries and Oceans Canada and other jurisdictions and/or organizations to help achieve the management objectives identified in the document. Implementation of this Management Plan is subject to appropriations, priorities, and budgetary constraints of the participating jurisdictions and organizations.

Acknowledgments

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Executive summary

The Wavyrayed Lampmussel is a sexually dimorphic, medium-sized freshwater mussel (75-100 mm long) that is easily distinguished from other mussels by its yellow or yellowish-green, rounded shell with numerous thin wavy green rays. This species is considered N1 (nationally critically imperilled) in Canada. The species was downlisted from Endangered to Special Concern under the *Species at Risk Act* following a reassessment by the Committee on the Status of Endangered Wildlife in Canada in 2010. The Canadian distribution is restricted to southern Ontario; the species is currently found in the St. Clair River delta and the Ausable, Grand, Maitland, Sydenham, and Thames rivers.

The primary threats to Wavyrayed Lampmussel populations are contaminants and toxic substances, nutrient loading, factors impacting the availability of host fish(es), the presence of aquatic invasive species (i.e., Zebra and Quagga mussels), turbidity and sediment loading, altered flow regimes, habitat removal and alterations, predation and harvesting, and recreational activities.

The objective (>20 years) of this management plan is to ensure the long-term persistence of Wavyrayed Lampmussel throughout its current range by maintaining or enhancing self-sustaining populations, and restoring degraded populations through habitat improvement initiatives where feasible.

The following short-term management objectives to be considered over the next 5-10 years have been identified to assist with meeting the long-term management objective:

i. To refine extent, abundance and population demographics of existing populations;
ii. To confirm host fish(es) in the field;
iii. To continue to monitor Wavyrayed Lampmussel habitat and the habitat of its host(s);
iv. To continue to evaluate threats impacting the Wavyrayed Lampmussel and its habitat and implement remedial actions to reduce their effects; and,
v. To continue to increase public awareness of the significance of the Wavyrayed Lampmussel and its status as a Canadian species at risk.

The short-term management objectives were adapted from the original *Recovery Strategy for the Wavyrayed Lampmussel (*Lampsilis fasciola*) in Canada (2006)* with updates to reflect the current species' status of Special Concern, as well as new information provided in the *Recovery Potential Assessment of the Wavyrayed Lampmussel (*Lampsilis fasciola*) in Canada (2010)*. Several single-species, multi-species, and ecosystem-based recovery planning documents already exist or are in development that include parts of the range of Wavyrayed Lampmussel populations in southwestern Ontario and will likely promote the conservation of this species in those areas.

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1. COSEWIC[a] species assessment information

Date of Assessment: April 2010
Common Name (population): Wavyrayed Lampmussel
Scientific Name: *Lampsilis fasciola*
COSEWIC Status: Special Concern
Reason for Designation: This medium-sized freshwater mussel is confined to four river systems[b] and the Lake St. Clair delta in southern Ontario. Since the original COSEWIC assessment of Endangered in 1999, surveys have identified a large, previously unknown reproducing population in the Maitland River. The mussels in the Thames River are also now reproducing. The largest population is in the Grand River; smaller but apparently reproducing populations are in the Ausable River and Lake St. Clair delta. Although water and habitat quality have declined throughout most of the species' former range in Canada, there are signs of improvement in some populations but habitats in Great Lakes waters are now heavily infested with invasive mussels and are uninhabitable for native mussels. The main limiting factor is the availability of shallow, silt-free riffle/run habitat. All riverine populations are in areas of intense agriculture and urban and industrial development, subject to degradation, siltation, and pollution. Invasive mussels continue to threaten the Lake St. Clair delta population and could be a threat to populations in the Grand and Thames rivers if they invade upstream reservoirs.
Canadian Occurrence: Ontario
COSEWIC Status History: Designated Endangered in April 1999. Status re-examined and confirmed in October 1999. Status re-examined and designated Special Concern in April 2010.

[a] COSEWIC – Committee on the Status of Endangered Wildlife in Canada
[b] This does not include the live individual that was found in the Sydenham River in 2013.

2. Species status information

Global status: The Wavyrayed Lampmussel (*Lampsilis fasciola,* Rafinesque, 1820) is globally listed as G5 (demonstrably widespread, abundant, and secure). In the United States, the Wavyrayed Lampmussel is considered secure, but there are states where this species is listed as critically imperilled and it is possibly extirpated in Mississippi (NatureServe 2014) (Table 1). Population declines have been observed throughout the United States' distribution range (Parmalee and Bogan 1998).

Canadian status: In Canada, the Wavyrayed Lampmussel has a national ranking of N1 and has a subnational ranking of S1 in Ontario (NatureServe 2014). In 2010, the Wavyrayed Lampmussel was designated a species of Special Concern by COSEWIC (COSEWIC 2010) and was listed as Special Concern under the federal *Species at Risk Act* (SARA) in 2013. It is listed as Threatened under Ontario's *Endangered Species Act*, 2007[1].

Percent of global distribution and abundance in Canada: The estimated extent of occurrence of the Wavyrayed Lampmussel in Canada is 14,153 km^2 (COSEWIC 2010). Less than 5% of the species' global distribution is found in Canada (Morris 2006). The current area

[1] As a species of special concern, the Wavyrayed Lampmussel is not protected by the automatic prohibitions under the *Species at Risk Act* that apply to species classified as Endangered, Threatened, or Extirpated; however, it is currently listed as Threatened under Ontario's *Endangered Species Act*, 2007, which provides protection for individuals of this species including its habitat.

of occupancy in the St. Clair River delta and the Ausable, Grand, Maitland, and Thames rivers is estimated at approximately 19.4 km^2 (COSEWIC 2010). Population estimates were calculated as the following by COSEWIC in 2010: Ausable River (33,600 [± 11,200]); Grand River (2,100,000[± 1,200,000]); Maitland River (310,000 [±86,400]); Thames River (325,000 [± 167,500]); and, St. Clair River delta (3,300 [± 1,100]).

Table 1: Canadian and U.S. national and provincial/state heritage status ranks (NatureServe 2014).

Rank	Jurisdiction Rank
Global (G)	**G5** (last reviewed 23 December 2011)
National (N)	
Canada	**N1** (21 May 2013)
United States	**N5** (12 July 2005)
Sub-national (S)	
Canada	ON (**S1**)
United States	AL (**S2**), GA (**S1**), IL (**S2**), IN (**S3**), KY (**S4S5**), MI (**S2**), NY (**S1**), NC (**S1**), OH (**S3**), PA (**S4**), TN (**S4**), VA (**S4**), WV (**S2**)

Source: NatureServe (2014)

The conservation status of a species or community is designated by a number from 1 to 5, preceded by a letter reflecting the appropriate geographic scale of the assessment (G = Global, N = National, and S = Subnational). The numbers have the following meaning: 1 = critically imperilled; 2 = imperilled; 3 = vulnerable to extirpation or extinction; 4 = apparently secure; 5 = demonstrably widespread, abundant, and secure. S#S#: Range rank – A numeric range rank (e.g., S2S3) is used to indicate the range of uncertainty in the status of a species or community. A S2S3 rank would indicate that there is a roughly equal chance of S2 or S3 and other ranks are much less likely. http://www.natureserve.org/explorer/ranking.htm

3. Species information

3.1 Species description

The following description has been derived from Morris (2006) and COSEWIC (2010). The Wavyrayed Lampmussel is a sexually dimorphic medium-sized mussel (75-100 mm long) that is easily distinguished from other mussels by its yellow or yellowish-green rounded shell with numerous thin wavy green rays. These rays may be narrow and individual or coalesced into wider rays (Figure 1), but, regardless of size, the rays are always wavy with multiple interruptions giving rise to the common name of this mussel.

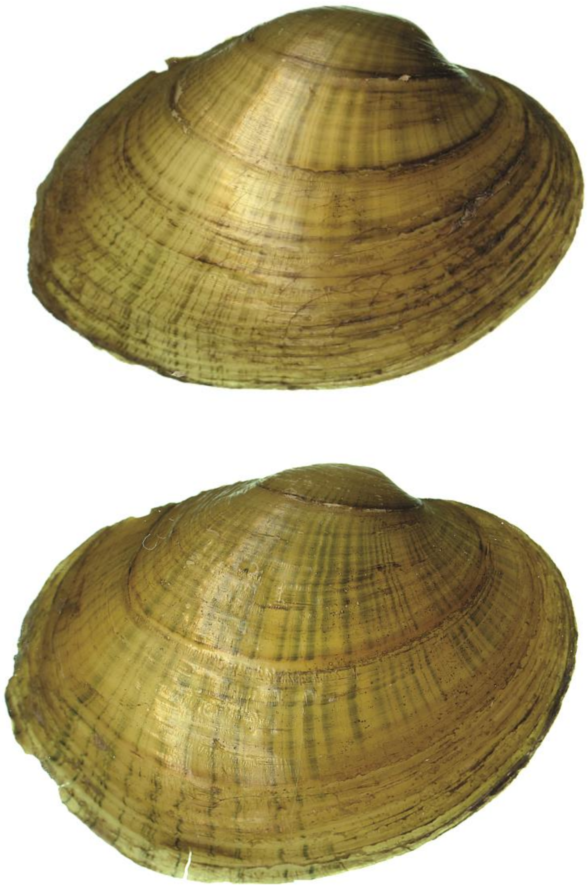

Figure 1: Male (top) and female (bottom) Wavyrayed Lampmussel (*Lampsilis fasciola*).

3.2 Population and distribution

Global range: In the United States, the Wavyrayed Lampmussel has been recorded from Alabama, Georgia, Illinois, Indiana, Kentucky, Michigan, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia (Figure 2). The current distribution of the Wavyrayed Lampmussel in the United States is similar to its historical distribution (NatureServe 2014). In Canada, the Wavyrayed Lampmussel is only found in Ontario (Figure 2 and 3) (NatureServe 2014).

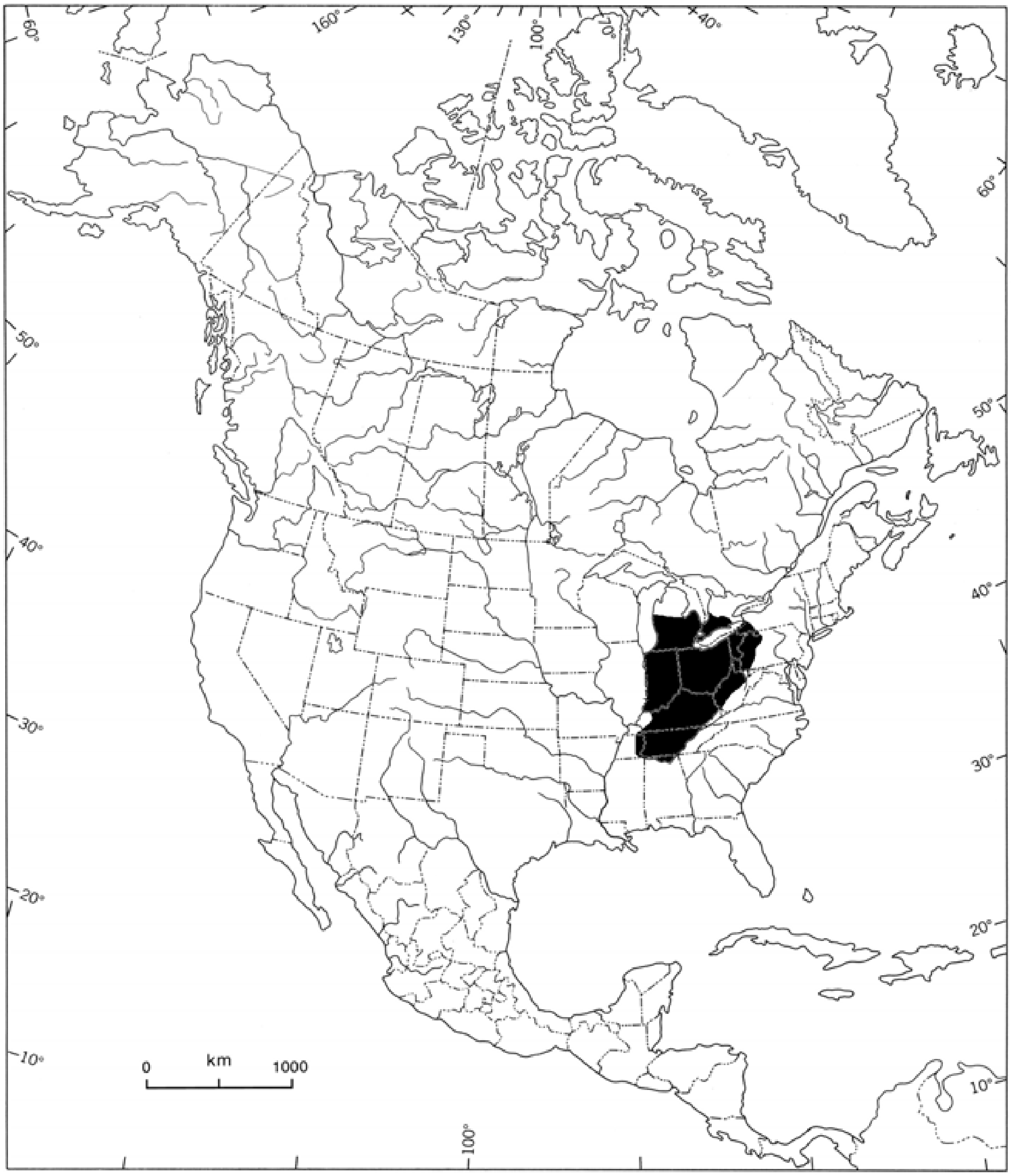

Figure 2: North American distribution of the Wavyrayed Lampmussel (modified from Parmalee and Bogan 1998).

Canadian range: The current distribution of the species, based on collections made between 1990 and 2013, is shown in Figure 3. Live specimens have been found in the Ausable, Grand, Maitland, Sydenham, and Thames (North and South) and St. Clair rivers, and in the St. Clair River delta. In 2013, a live specimen was found in the Sydenham River; it was the first live specimen recorded from this river since 1971 (D. Balint, Fisheries and Oceans Canada [DFO], pers. comm.).

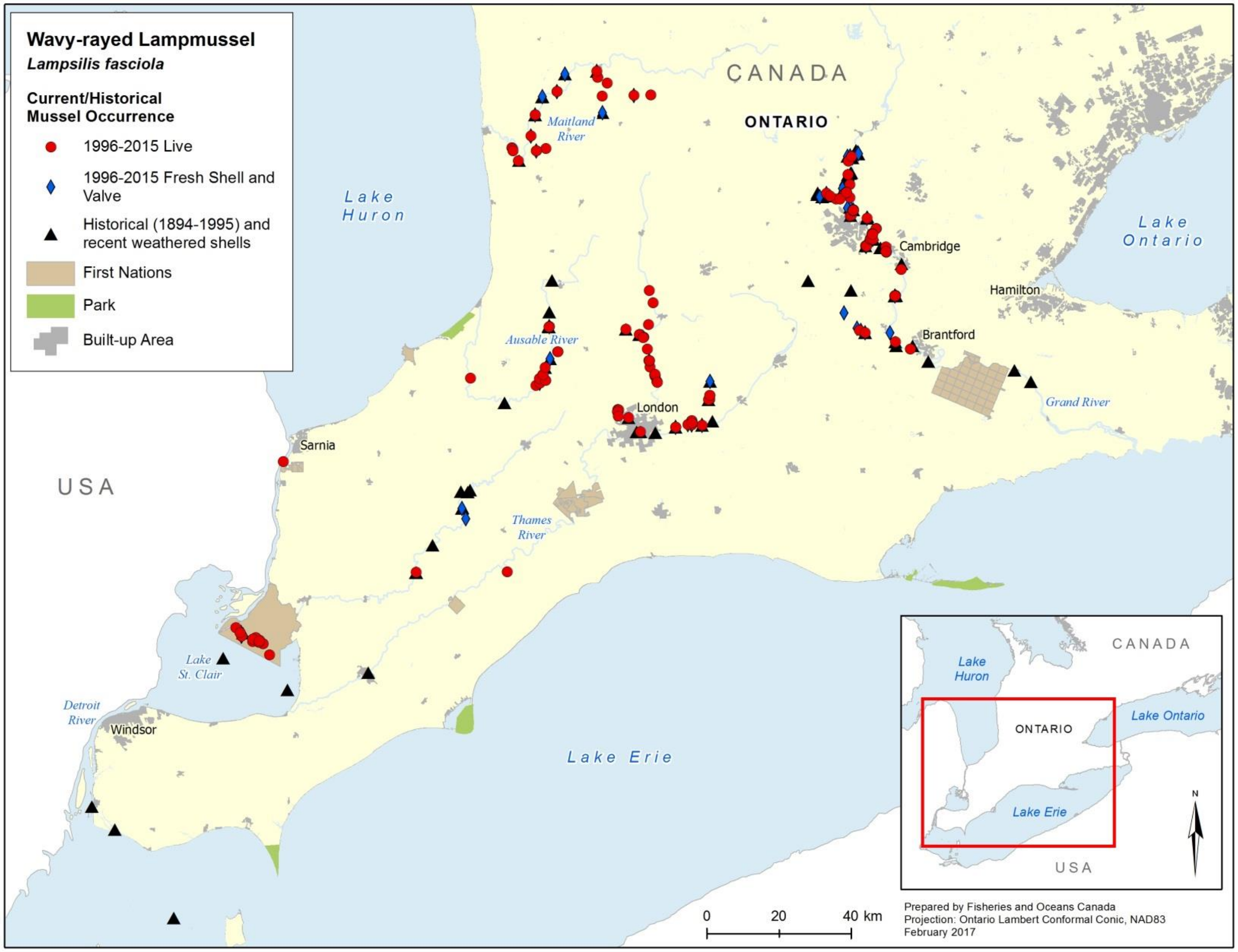

Figure 3: Current distribution of Wavyrayed Lampmussel in Canada.

Canadian population size: Canadian population estimates for the Wavyrayed Lampmussel were developed by Bouvier and Morris (2010); see Table 2 for detailed information. The following descriptions of the known occurrences of Wavyrayed Lampmussel in Canada were adapted from Bouvier and Morris (2010), while survey data from 2010-2013 were obtained from the Ontario Freshwater Mussel Database.

Ausable River: The first population of Wavyrayed Lampmussel was found in the Ausable River in 1993 (Morris and Di Maio 1998). It has since been found in Nairn Creek, the Little Ausable River and the main stem of the Ausable River. Between 1993 and 2005, only three individuals were discovered during sampling efforts; a timed-search in 2002 found two individuals and an observational study in 2005 found one juvenile. Quadrate surveys completed in 2006 by DFO and the Ausable Bayfield Conservation Authority (ABCA) found 18 specimens at five sites (Baitz et al. 2008). The ABCA has also reported one live individual found during a timed-search done in 2008 (ABCA, unpubl. data). Various surveys conducted between 2010 and 2013 found 34 live individuals.

Grand River: This population appears to have recovered from poor water quality conditions present in the Grand River in the 1970s and early 1980s (Morris 2006) to become one of the healthiest Canadian populations (Table 2; Morris 2006). Wavyrayed Lampmussel occurs from Inverhaugh downstream to Glen Morris within the Grand River watershed (Morris et al. 2008; COSEWIC 2010), and has also been found in three Grand River tributaries, including 13.5 km of the Conestogo River, 30 km of the Nith River, and the lower portion of the Speed River (10 km; COSEWIC 2010).

Between 1995 and 1998, 22 live animals, 38 fresh whole shells, and seven fresh half-shells were discovered from 11 sites, including two sites on the Nith River and one on the Conestoga River (both tributaries of the Grand) (Mackie 1996; Metcalfe-Smith et al. 1998; Metcalfe-Smith et al. 1999). From 2001 to 2006, 73 live individuals, 20 fresh whole shells, and seven fresh half-shells were found. Between May and October of 2006, a mark and recapture study, in which one plot was sampled 13 times, found 88 unique individuals (DFO, unpubl. data), while two relocation studies conducted in 2006 noted 254 live individuals (G. Mackie, University of Guelph, unpubl. data). Various surveys conducted between 2009 and 2012 noted 266 live individuals, seven fresh whole shells, 12 weathered whole shells, and seven weathered valves from 23 sites. Four live individuals were also found in the Conestogo River, and 44 live individuals in the Speed River. Most recently, in 2013, 31 live individuals and two fresh whole shells were found at five sites.

Maitland River: Wavyrayed Lampmussel has been found in all four branches of the Maitland River watershed. It occurs over a 23 km stretch in the Middle Maitland River, 15 km in the Little Maitland River, 54 km in the main stem, and 10 km in the South Maitland River. Sampling conducted from 1997 to1998 noted three live individuals and three whole shells. Timed-search sampling completed between 2003 and 2004 found 21 live individuals at nine sites. In 2008, the species was recorded at three of these previously sampled sites and one additional site. A behaviour study conducted in 2009 at one site found 73 live individuals, while in 2010 a timed-search survey (1.5 person-hours [p-h]) using visual search viewing boxes found only two live individuals. In July and October 2012, timed-search surveys revealed nine live individuals at five sites in the Maitland River.

Thames River: Wavyrayed Lampmussel currently occupies all of its known historic range in the Thames River; it occurs over 65 km of the North, South, and Middle branches of the Thames River upstream of the city of London, in addition to two tributaries of the North Thames branch

(Fish and Medway creeks). As indicated in surveys conducted in 2004, one of the healthiest populations remaining in Canada is located in the North Thames River. Further, size and age distributions indicate that recruitment is occurring throughout most of the sites. Sampling conducted from 2006-2008 found 75 live individuals, and 138 unique live individuals were noted during a mark-recapture study in which one plot was sampled 14 times between May and October. In 2009, 139 live individuals were found in the North Thames River, while in 2010, sixteen live individuals were found in Medway Creek and two live individuals in the Thames River. From 2011 to 2012, various surveys found 208 live individuals and 15 fresh whole shells in the Thames River, along with two live individuals in Medway Creek. Most recently, in 2013, 38 live individuals and one fresh whole shell were found, including seven live individuals at a relocation site.

Sydenham River: In 2013, the first live Wavyrayed Lampmussel was found in the Sydenham River since 1971, despite intensive sampling from 1997-2003 (over 600 p-h). Wavyrayed Lampmussel was thought to be extirpated from the Sydenham River (COSEWIC 2010). The historical distribution of the Wavyrayed Lampmussel included the middle reach of the East Sydenham River.

St. Clair River and Delta: Wavyrayed Lampmussel was detected for the first time in the St. Clair River in 2001 by the National Water Research Institute just south of Sarnia. No further specimens have been detected in the river since this time. The St. Clair River Delta population can be found over 12 km^2 of the shallow nearshore areas of the delta within the territory of Walpole Island First Nation. Sampling from 1999 to 2005 noted 34 live individuals and, most recently, in 2011 sampling noted four live individuals and one fresh whole shell at three sites, indicating that the St. Clair River Delta population appears to be the last historical lake population to persist. The Lake St. Clair population was decimated following the introduction of the Zebra Mussel to the Great Lakes.

Current Status and Population Estimates within Canadian Range

The COSEWIC status of Wavyrayed Lampmussel was re-examined and designated Special Concern in 2010. Extensive quantitative surveys and long-term monitoring have been conducted since the original COSEWIC assessment of Endangered in 1999; a comprehensive list of sampling efforts (1990-2008) is catalogued in the Wavyrayed Lampmussel COSEWIC report (COSEWIC 2010).

Populations are showing signs of improvement; population estimates have risen, area of occupancy has increased two to three fold, and relative abundances have increased from 2-4% to 20-50% in some watersheds. In 2013, the first live individual was found in the Sydenham River since 1971.

Population estimates from quantitative sampling (Table 2) indicate the Grand River supports the largest population in Canada, while the Thames and Maitland river populations (similar to one another) are an order of magnitude lower than the Grand River. The Ausable River and St. Clair River delta still support remnant populations two to three orders of magnitude smaller than the Grand River. These population estimates should be interpreted with caution as, in all cases except the St. Clair River delta, they assume a continuous, homogenous distribution throughout the occupied reach, and sampling was usually done in the most productive areas of the reach. As such, they likely represent a maximum population estimate. Further sampling in the Sydenham River is required. No population estimates are available for the St. Clair River due to the limited detections that have been made in this waterbody.

Table 2. Estimated population sizes for Wavyrayed Lampmussel based on quantitative surveys within the area of occupancy. Population data are as recent as 2010.

Waterbody	Total Unionid Density (#/m^2) (SE)	WRLM Density (#/m^2) (SE)	WRLM Area of Occupancy[d] (km^2)	WRLM Estimated population size[d] (± SE)[e]
Ausable River	5.98 (2.526)[a]	0.048 (0.016)[a]	0.7	33,600 (± 11,200)
Grand River	0.89 (0.289)[b]	0.28 (0.16)[b]	7.5	2,100,000(± 1,200,000)
Maitland River	1.21 (0.402)[b]	0.096 (0.027)[b]	3.2	310,000 (±86,400)
Thames River	1.57 (0.618)[b]	0.13 (0.067)[b]	2.5	325,000 (± 167,500)
St. Clair River delta	0.096 (0.008)[c]	0.0006 (0.00021)[c]	5.5	3,300 (± 1,100)

[a] ABCA (unpubl. data); [b] DFO (unpubl. data); [c] Metcalfe-Smith et al. (2007); [d] COSEWIC (2010); [e] Standard Error (SE)

3.3 Needs of the Wavyrayed Lampmussel

Habitat and biological needs

Spawning: During spawning, males release sperm into the water and females located downstream use their incurrent siphons to intake the sperm to fertilize the eggs. Females brood the young from egg to larval stage in the posterior portions of the outer gills (Metcalfe-Smith et al. 2000). Spawning occurs in August and the glochidia are released the following year in June through August (Woolnough 2002), undergoing a period of encystment by attaching to the gills of a suitable host fish. Mature female Wavyrayed Lampmussel have developed specialized mantel tissue to function as a lure in order to attract suitable host fish(es) (Strayer and Jirka 1997). When a suitable host touches the lure, the mantle retracts causing the release of the glochidia. At least four different lure morphologies have been observed on displaying females during field surveys, with all four morphologies occurring at the same time in the same mussel beds (Figure 4). There is currently limited information available to determine whether the four lure morphologies exhibited by the Wavyrayed Lampmussel are ectomorphs or are representative of sibling species that are reproductively isolated. Zanatta et al. (2007) did not detect genetic differences that would indicate that the morphs are sibling species; however, they qualify this finding with the fact that their results might have been impacted by low sample sizes. For this reason, molecular phylogenetic analysis may be necessary to properly address this question (Morris 2006).

Encysted glochidia stage: The glochidia become encysted on the host(s) anywhere from a few weeks to several months. Once the glochidia metamorphose into juveniles, they release themselves from the gills of the host fish(es) and fall to the substrate (COSEWIC 2010). Confirmed laboratory hosts for the Wavyrayed Lampmussel are Brook Stickleback (*Culaea inconstans*), Largemouth Bass (*Micropterus salmoides*), Mottled Sculpin (*Cottus bairdii*), and Smallmouth Bass (*M. dolomieu*) (McNichols et al. 2005, 2011).

Juvenile: Once the juveniles fall to the substrate, they begin life as free-living mussels. They quickly burrow into the sediment and remain buried until they are sexually mature. During this burrowing period, they are likely feeding on a combination of detritus, algae, and bacteria found in the substrate or in the interstitial water (Wächtler et al. 2000). When the juveniles reach sexual maturity (sexual maturity of Wavyrayed Lampmussel in the Grand and Thames rivers occurs at three to four years [Morris et al. 2008]), they move to the substrate surface to disperse or intake gametes (Watters et al. 2001).

Adult: The Wavyrayed Lampmussel is mainly found in medium-sized streams in gravel or sand bottoms of riffle areas (Clarke 1981; Cummings and Mayer 1992). Strayer and Jirka (1997) reported Wavyrayed Lampmussel in rivers and large creeks that had clear water with steady flows and stable substrates. The species has also been found on outwash plains of medium-sized and large streams in southeastern Michigan (Strayer 1983). Recent and historical mussel records for the Tennessee River basin were examined and it was found that Wavyrayed Lampmussel typically inhabit 2nd to 7th order streams, and can occupy muddy gravel substrates and tolerate some silt deposition during periods of low flow (Dennis 1984).

Morris (2006) describes the species' functional habitat requirements as being permanently wetted, medium to large streams with clear, steadily flowing waters and a substrate composition of sand/gravel often stabilized by rubble, boulder or bedrock. Riverine populations occur in a stream order greater than two with riffle/run habitat, whereas the Great Lakes populations are found in shallow sand flats (Morris 2006).

The dispersal ability of adult Wavyrayed Lampmussel is limited. Although adult movement can be directed upstream or downstream, studies have found a net downstream movement through time (Balfour and Smock 1995). The primary means for large-scale dispersal, upstream movement, and the invasion of new habitat or evasion of deteriorating habitat, is limited to the encysted glochidial stage on the host fish(es) (Morris 2006).

Ecological role: Freshwater mussels perform vital water column and sediment processes that contribute to the functioning of aquatic ecosystems (Vaughn and Hakenkamp 2001). They also play an important role in the transfer of energy to the terrestrial environment through predation by Muskrat (*Ondatra zibethicus*) and Raccoon (*Procyon lotor*) (Neves and Odom 1989). Freshwater mussels are sensitive indicators of the quality of water and habitat, the quality of which can also affect the host fish species they depend on for successful reproduction.

Limiting factors: There are multiple intrinsic factors that may limit the Wavyrayed Lampmussel including: a complex life cycle, restricted ability to move as an adult, dependency on a host fish(es) for successful reproduction, and increased sensitivity to environmental contaminants. The glochidium of Wavyrayed Lampmussel has been shown to be acutely sensitive to sodium chloride/contaminant exposure (Gillis 2011), while juvenile freshwater mussels may increase their exposure to sediment-bound contaminants during the first few years of life when they are buried in the sediment (Yeager et al. 1994).

Figure 4: Typical examples of mantle diversity in the Wavyrayed Lampmussel: (A) orange, no appendages, no eyespot; (B) hellgrammite-like, dark, generally patternless dorsum contrasting with lighter sides (sublateral), dark pigment extends lobe-like into lighter area, lacks eyespot, simple appendages; (C) darter-like variants, midlateral spots, often with dorsal spots, simple appendages, distinct eyespot; and, (D) other variable fish-like or crayfish-like display, “flamboyant attractor”, gaudy colours and patterns, some compound (branched) appendages, eyespot present but not well-defined (Morris et al. 2008).

4. Threats

4.1 Threat assessment

Table 3 summarizes threats to the Wavyrayed Lampmussel populations in Canada (Bouvier and Morris 2010). To assess the Threat Status of Wavyrayed Lampmussel populations, each threat was ranked in terms of the Threat Likelihood and Threat Impact on a population basis (see Bouvier and Morris 2010 for details). The Threat Likelihood was assigned as Known, Likely, Unlikely, or Unknown, and the Threat Impact was assigned as High, Medium, Low, or Unknown. The Threat Likelihood and Threat Impact for each population were subsequently combined in the Threat Status matrix resulting in the final Threat Status for each population (Table 3). Certainty has been classified for Threat Impact and is based on: 1 = causative studies; 2 = correlative studies; and, 3 = expert opinion.

Table 3. Threat Status for all Wavyrayed Lampmussel populations, resulting from an analysis of both the Threat Likelihood and Threat Impact. The number in brackets refers to the level of certainty assigned to each Threat Status, which relates to the level of certainty associated with Threat Impact. Certainty has been classified as: 1= causative studies; 2=correlative studies; and, 3=expert opinion. Gray cells indicate that the threat is not applicable to the population due to the nature of the aquatic system where the population is located. Clear cells do not necessarily represent a lack of a relationship between a population and a threat; rather, they indicate that either the Threat Likelihood or Threat Impact was Unknown.

Threats	Ausable River	Grand River	Maitland River	Thames River
Aquatic invasive species	Medium (2)	High (2)	Medium (2)	High (2)
Turbidity and sediment loading	High (2)	Medium (2)	Medium (2)	Medium (2)
Contaminants and toxic substances	High (1)	High (1)	High (1)	High (1)
Nutrient loading	High (2)	High (2)	High (2)	High (2)
Altered flow regimes	Medium (2)	High (2)	Medium (2)	High (2)
Habitat removal and alteration	Medium (3)	Medium (3)	Medium (3)	Medium (3)
Host fish(es)	Medium (2)	High (2)	Medium (2)	High (2)
Predation and harvesting	Low (3)	Low (3)	Low (3)	Low (3)
Recreational activities	Low (3)	Low (3)	Low (3)	Low (3)

Threats	St. Clair River delta	Lake Erie and connecting channels	Sydenham River
Aquatic invasive species	High (2)	High (2)	Medium (2)
Turbidity and sediment loading	Medium (2)	Medium (2)	High (2)
Contaminants and toxic substances	High (1)	High (1)	High (1)
Nutrient loading	High (2)	High (2)	High (2)
Altered flow regimes		Low (3)	Medium (2)
Habitat removal and alteration	Low (3)	Low (3)	Low (3)
Host Fish(es)	High (2)	High (2)	High (2)
Predation and harvesting	Low (3)	Low (3)	Low (3)
Recreational activities	Low (3)	Low (3)	Low (3)

N.B. The Threat Status represents a combination of the ***current*** *Threat Impact and Threat Likelihood at a location. It* ***does not*** *reflect the potential impact a threat might have on a population if it was allowed to occur in the future.*

4.2 Description of threats

The following are brief descriptions of the principal threats that are currently affecting Wavyrayed Lampmussel populations throughout Ontario. Much of the information has been summarized from Bouvier and Morris (2010) and from DFO (2016a).

Contaminants and toxic substances: The life-history characteristics of freshwater mussels make them particularly sensitive to increased levels of sediment contamination and water pollution. Adult mussels are primarily filter feeders of suspended organisms, while juvenile unionids of the closely related Rainbow Mussel (*Villosa iris*) have been documented to burrow and filter feed within interstitial spaces in the sediment where phytoplanktonic and bacterial organisms, as well as allochthonous particulate matter, are present (Yeager et al. 1994). Although a multitude of contaminants and toxic substances are present where Wavyrayed Lampmussel occurs, this species is particularly sensitive to copper and unionized ammonia (Gillis et al. 2008; Morris et al. 2008 and references therein). Copper concentrations exceeded federal guidelines issued by the Canadian Council of Ministers of the Environment (CCME) in several sub-basins of the Thames River (Metcalfe-Smith et al. 2000b), while the mean ammonia concentration in the Thames River exceeded federal guidelines in all sub-basins (Morris et al. 2008). Wavyrayed Lampmussel was found at some of the study sites in the upper reaches of the Grand River where copper levels were within federal guidelines (Metcalfe-Smith et al. 2000b).

Glochidia of Wavyrayed Lampmussel have been shown to be highly sensitive to sodium chloride (Gillis 2011). As the distribution range of Wavyrayed Lampmussel is limited to Canada's most road-dense and heavily salted region, chloride from road salt poses a significant threat to the species. Chloride in mussel habitats has been reported at levels (>1300 mg/L) that are acutely toxic to Wavyrayed Lampmussel (Gillis 2011). The current federal water quality guidelines for the protection of aquatic life have been set at 120 mg/L for chronic exposure to chloride, a level that may not sufficiently protect glochidia of some at-risk mussel species (CCME 2011). Todd and Kaltenecker (2012) have done work that suggests long-term road salt use is contributing to increases in baseline chloride concentrations in the habitats of mussel species at risk in southern Ontario, which may negatively affect recruitment of at-risk mussel populations.

Anthropogenic stressors, such as sewage pollution, have been reported as being responsible for much of the harm to freshwater mussel communities downstream of urban centres along the Grand River (Mackie 1996). The predicted increase in the human population of these urban areas will lead to an increase of wastewater discharge through urban runoff and municipal wastewater effluent. An assessment of the cumulative impacts of wastewater and road runoff pollution on freshwater mussels in the Grand River found that simultaneous chronic exposure to multiple contaminants (e.g., ammonia, chloride and metals such as Cu, Pb, and Zn) contributed to the decline of the population downstream of an urban centre (Gillis 2012). A follow-up study completed by Gillis (unpublished) revealed a "dead zone" immediately downstream of a wastewater treatment outfall near Kitchener where no live mussels were detected for several kilometers (P. Gillis, Environment and Climate Change Canada, pers. comm). Municipal wastewaters may also affect endocrine and reproductive functions of aquatic organisms. Feminization of fishes has been documented in the Grand River (Tetreault et al. 2011), and although such impacts have not been documented for mussels in southern Ontario, downstream of a municipal wastewater effluent outfall in Quebec, the gonad physiology and reproduction of Eastern Elliptios (*Elliptio complanata*) was disrupted by pollution. In the mussel population downstream of the outfall, there was a dramatic increase in the proportion of females, in addition to males that showed a female-specific protein (Gagné et al. 2011). However, Gillis (2012) concluded that sample numbers of 15 individuals or less are not adequate to assess the possibility that feminization is occurring in a freshwater mussel population.

Nutrient loading: Increases in phosphorus and nitrogen can lead to algal blooms that subsequently decrease the amount of dissolved oxygen. Freshwater mussels are particularly sensitive to decreases in dissolved oxygen. A negative correlation has been found between concentrations of phosphorus and nitrogen and Wavyrayed Lampmussel abundance in different southwestern Ontario streams (Morris et al. 2008).

The Thames River watershed has some of the highest loadings of phosphorus and nitrogen for the entire Great Lakes basin (WQB 1989b; Morris 2006), resulting from tile drainage, wastewater drains, and manure storage and spreading (Metcalfe-Smith et al. 2000b). Poor water quality in the Ausable and Sydenham rivers, where agriculture is the primary land use, is attributed to agricultural runoff and manure seepage (ARRT 2005; Morris 2006). Agricultural runoff in the Maitland River causes nitrate values to often exceed federal guidelines in this system (Morris 2006).

Host fish(es): Due to the necessity of a suitable host fish for the obligate glochidial encystment stage of the Wavyrayed Lampmussel life cycle, any factors that affect the host fish(es) or prevent access to host fish(es) may impact Wavyrayed Lampmussel populations and distribution. A decline or disappearance in host fish populations to levels below that which can sustain a mussel population may result in the mussel species becoming functionally extinct (Bogan 1993).

Laboratory infestation experiments have determined four host fishes for the Wavyrayed Lampmussel in Canada: Brook Stickleback, Largemouth Bass, Mottled Sculpin and Smallmouth Bass (McNichols et al. 2005, 2011). Due to the specialized "lure" that female mussels use to attract hosts, functional hosts in natural settings are likely visual predators such as Smallmouth and Largemouth bass (Morris et al. 2005). All of these fish species are present throughout the Ontario range of the Wavyrayed Lampmussel and their populations are considered secure (NatureServe 2014). Smallmouth Bass is thought to be the most likely natural host. Populations of Smallmouth Bass in the Ausable, Maitland, and Thames rivers appear to have remained stable or have increased over the past 20 years (Morris et al. 2008). Smallmouth Bass populations, though relatively stable, are rare in the Sydenham River, which may explain the decline of Wavyrayed Lampmussel in this system (Morris et al. 2008).

Threats to host fish(es), which in turn can affect the reproductive cycle of freshwater mussels, include:

- Decreased water quality which can create unsuitable habitat;
- Increased turbidity which can reduce visibility, impacting the ability of host fish(es) to see the mussel's lure and subsequently become infested with glochidia;
- Impoundments and dams create barriers to movement that can separate host fish(es) from the mussel and/or limit the dispersal of the mussel. The addition of fish ladders on dams in the Grand River have allowed for increased mussel dispersal through the host fish(es), leading to an improved mussel community in this system (Metcalf-Smith et al. 2000a).

Aquatic invasive species: The invasion and spread of Zebra Mussel (as well as Quagga Mussel) throughout the Great Lakes and their tributaries has severely affected many native freshwater mussel populations (e.g., Nalepa et al. 1996; Ricciardi et al. 1996; Schloesser et al. 1996; Schloesser et al. 1998; Zanatta et al. 2002). Lacustrine habitat that historically supported populations of Wavyrayed Lampmussel has been devastated by Zebra Mussel, including both western Lake Erie (Schloesser and Nalepa 1994) and Lake St. Clair (Nalepa et al. 1996); however, the St. Clair River Delta contains the last remaining lake population of Wavyrayed Lampmussel in Canada (Morris 2006). Zebra Mussel could pose a risk to riverine populations of freshwater mussels if it becomes established in reservoirs. Zebra Mussel has been reported in two reservoirs on the Thames River (Upper Thames River Conservation Authority 2003); however, these are downstream of the Wavyrayed Lampmussel populations. An infestation of Zebra Mussel upstream of riverine populations could potentially be detrimental to freshwater mussel communities. The 34 dams/weirs in the Grand River (Grand River Conservation Authority 1998) also make this population of Wavyrayed Lampmussel susceptible to an infestation of Zebra Mussel, which has already occurred in the Luther, Belwood, Guelph, and Conestogo reservoirs (Metcalfe-Smith et al. 2000a; Morris 2006).

The invasion of Zebra Mussel negatively impacts the survivorship of freshwater unionid species, such as the Wavyrayed Lampmussel, through its epizoic colonization of unionid mussel shells, as well as the benthic substrates where they subsist (Schloesser and Nalepa 1994). Such fouling of unionid mussel shells is believed to impact feeding, respiration, excretion, as well as locomotion, leading to eventual death by starvation (Ricciardi et al. 1998).

The Wavyrayed Lampmussel may also be indirectly affected by invasive fish species such as the Round Goby (*Neogobius melanostomus*). It is possible that such invaders may impact host fish relationships that are critical to the life cycle of the Wavyrayed Lampmussel (Metcalfe-Smith et al. 2000). For example, the Mottled Sculpin, which is an established host fish of the Northern Riffleshell (*Epioblasma torulosa rangiana*) and Wavyrayed Lampmussel (McNichols et al. 2011), has experienced recruitment failure and population declines as a result of Round Goby invasion (Dubs and Corkum 1996; Janssen and Jude 2001). Furthermore, Round Goby invasions have been detected in the lower reaches of the Sydenham, Ausable, Thames, and Grand rivers between 2003 and 2008 (Poos et al. 2010).

Turbidity and sediment loading: The quantity and quality of Wavyrayed Lampmussel habitat across its Ontario range has been degraded due to an increase in turbidity and a decrease in silt-free riffle/run habitats (Morris et al. 2008). Suspended solids in the water can negatively affect mussels physically by clogging gill structures and inhibiting oxygen intake, and also reproductively as host fish(es) need to be able to visually locate the lure to become infested with glochidia (Morris 2006). Though Dennis (1984) indicated that Wavyrayed Lampmussel in the Tennessee River basin could tolerate high silt conditions during periods of low flow, a recent study has shown that catch-per-unit effort for Wavyrayed Lampmussel is positively correlated with water clarity (Metcalfe-Smith and McGoldrick 2003). Increased sediment loads are frequently found in areas in which riparian vegetation has been cleared or livestock have unrestricted access to the river as part of agricultural land use (WQB 1989a; Morris 2006). Increased land drainage can also add large amounts of sediments to the watercourse, while erosion can result in siltation and shifting substrates that can smother mussels.

Altered flow regimes: Mussels can be negatively affected in multiple ways by the presence of impoundments and dams. Downstream flow patterns are altered and natural thermal profiles of systems are disrupted due to reservoirs. Impoundments act as barriers, potentially separating mussels from their host fish(es) and reducing mussel dispersal during the period of glochidial encystment. Impoundments can also result in siltation, stagnation, loss of shallow water habitat and poor water quality due to high nutrient concentrations and accumulation of pollutants. Impoundments increase water retention time, which makes the system more susceptible to colonization of invasive species, such as Zebra Mussel, and can also lead to a change in species composition. After the construction of the Wilson Dam in 1925, the Wavyrayed Lampmussel was extirpated from the Tennessee River (Metcalfe-Smith et al. 2000b), while dams and impoundments constructed during the 1950’s on the South Fork Holston River in Tennessee led to the extirpation of Wavyrayed Lampmussel in that system.

Freshwater mussels can be negatively affected by both high- and low-flow conditions. High flows can dislodge mussels from the substrate while low flows can lead to low dissolved oxygen, silt accumulation, elevated temperatures and, potentially, desiccation (DFO 2016b). Freshwater mussels are vulnerable to low water levels as they are frequently found in very shallow water (10-20 cm) (Metcalfe-Smith et al. 2007). A negative correlation has been found between mean annual stream flow and the growth of many different freshwater mussel species (Rypel et al. 2008), indicating that impoundments and artificially altered flows can significantly affect mussel communities (DFO 2016b).

Habitat removal and alteration: Removal and alteration of preferred Wavyrayed Lampmussel habitat can occur through many types of human activities. Dredging and channelization of watercourses can directly destroy mussel habitat and cause local and downstream siltation and sand accumulation. The drainage of land for agricultural purposes can lead to large inputs of sediment into the watercourse, decreasing habitat quality.

Although quantitative information is not currently available regarding the number of Wavyrayed Lampmussel affected by human activities in Canada, the prevalence of this species could be directly affected by preferred habitat removal and alteration (Bouvier and Morris 2010).

Predation and harvesting: Historically, healthy populations of mussels were not affected by Muskrat predation; however, populations that are presently reduced to low densities and isolated by anthropogenic influences are negatively impacted by Muskrat predation (Neves and Odom 1989). Muskrat and Raccoon are significant predators of freshwater mussels, with these two species choosing Wavyrayed Lampmussel when available (Neves and Odom 1989). Predation would normally be considered a natural limiting factor, not a threat; however, anthropogenic changes in land use practices have led to substantial increases in the abundance of these predators. For example, the recent use of conservation tilling practices has led to substantially higher abundances of predators, which consequently could contribute to higher predation rates on mussel species (Metcalfe-Smith and McGoldrick 2003).

Harvesting mussels for human consumption could be a potential concern. In one recorded incident where human consumption was apparent, Wavyrayed Lampmussel shells were found alongside other discarded freshwater mussel shells (J. Barkley, DFO, pers. comm.).

Recreational activities: Recreational activities that may impact mussel beds include (Bouvier and Morris 2010):

- All-terrain vehicles (ATVs) driving through the riverbeds have the potential to crush mussel beds. This activity has been observed on the Thames, Ausable, and Sydenham rivers.
- Propellers of recreational boats and jet skis can leave channels on the bottom substrate. This has been noted through mussel beds in the St. Clair River delta.

5. Management objective

5.1 Long-term objective

The long-term objective (>20 years) of this management plan is to ensure the persistence of Wavyrayed Lampmussel throughout its current range by maintaining or enhancing self-sustaining populations, and restoring degraded populations through habitat improvement initiatives where feasible.

5.2 Objectives

The following short-term management objectives to be considered over the next 5-10 years have been identified to assist with meeting the long-term objective:

i. To refine extent, abundance and population demographics of existing populations;
ii. To confirm host fish(es) in the field;
iii. To continue to monitor Wavyrayed Lampmussel habitat and the habitat of its host(s);
iv. To continue to evaluate threats impacting the Wavyrayed Lampmussel and its habitat and implement remedial actions to reduce their effects; and,
v. To continue to increase public awareness of the significance of the Wavyrayed Lampmussel and its status as a Canadian species at risk.

6. Broad strategies and conservation measures

6.1 Actions already completed or currently underway

The following is a brief summary of the recovery measures prescribed for implementation in the original recovery strategy for the species (many of which are ongoing); it has been adapted from the five-year recovery strategy progress report for the Wavyrayed Lampmussel (DFO 2013b).

Research and monitoring activities

- Continued host fish testing; determined distribution and abundance of the host species;
- Continued identification of the habitat requirements for all life stages;
- Ongoing examination of the feasibility of translocations and reintroductions;
- Ongoing comparison of genetic variability within and among Canadian populations, as well as between Canadian and U.S. waterways, to determine if populations show genetic structure;
- Established a network of permanent monitoring stations throughout historical and present ranges;
- Established permanent monitoring sites for tracking changes in habitat; and,
- Ongoing identification and evaluation of threats to various life stages.

Management

- Continued transfer of knowledge and enhancement of expertise in freshwater mussel identification/biology through workshops, development of mussel guides and standardization of mussel sampling and relocation techniques; and,
- Ongoing collaboration between existing ecosystem recovery programs to implement recovery actions.

Stewardship

- Ongoing implementation of agricultural best management practices and other habitat enhancement projects in the Ausable, Sydenham, Thames, and Grand rivers.

Awareness

- Ongoing outreach conducted by various organizations in the Ausable River, Sydenham River and Thames River watersheds as well as at the Walpole Island Heritage Centre has encouraged public support and participation in stewardship activities; and,
- Presentations have been delivered by DFO staff at multiple conferences and to different naturalist groups and schools.

Further recovery initiatives and activities may be afforded to Wavyrayed Lampmussel populations in Ontario indirectly, as they are found within the range of existing species- and ecosystem-based recovery strategies or action plans. It is expected that Wavyrayed Lampmussel will receive substantial benefit from these complementary recovery initiatives. Both single and multi-species draft recovery strategies have been written previously for several freshwater mussel species whose distributions partly overlap with the Wavyrayed Lampmussel. Single- and multi-species recovery strategies for which recovery actions are currently being implemented include:

- Recovery Strategy for the Eastern Sand Darter (*Ammocrypta pellucida*) in Canada: Ontario Populations (DFO 2012)
- Recovery Strategy for the Northern Riffleshell, Snuffbox, Round Pigtoe, Salamander Mussel, and Rayed Bean in Canada (DFO 2016c)
- Recovery Strategy for the Round Hickorynut (*Obovaria subrotunda*) and the Kidneyshell (*Ptychobranchus fasciolaris*) in Canada (DFO 2013a)

Ecosystem-based recovery strategies/action plans that overlap with the Wavyrayed Lampmussel include:

- *Sydenham River Action Plan*: This action plan is a multi-species, ecosystem-based plan that addresses the needs of seven freshwater mussels as well as two species of fishes – the Eastern Sand Darter and Northern Madtom (*Noturus stigmosus*) (DFO 2016b). The plan builds on the recovery program established ten years earlier by the Sydenham River Recovery Team (Dextrase et al. 2003); it targets stewardship actions for maximum effectiveness in threat mitigation at the landscape level to recover multiple aquatic species at risk that share similar threats and habitat. A network of monitoring sites for mussel species at risk was established in 2003 (see Metcalfe-Smith et al. 2007).
- *Ausable River ecosystem recovery strategy* (Ausable River Recovery Team 2006): Stewardship efforts are ongoing and a monitoring program to track the recovery of endangered freshwater mussels in the Ausable River has been established (Baitz et al. 2008).

- *Thames River ecosystem recovery strategy*: The goal of the strategy is to develop "a recovery plan that improves the status of all aquatic species at risk in the Thames River through an ecosystem approach that sustains and enhances all native aquatic communities" (Thames River Recovery Team 2005). This recovery strategy addresses 25 COSEWIC-designated species, including seven mussels, 12 fishes, and six reptiles. Following the lead of the Sydenham Recovery Team, mussel-monitoring stations have been established in the Thames River.
- *Grand River fish species at risk recovery strategy* (Portt et al. 2007): While this recovery strategy deals specifically with fish species, many of the same threats apply to the Wavyrayed Lampmussel, such as the impacts of sediment and nutrient loadings and invasive species. The plan also includes host fishes of the Wavyrayed Lampmussel.
- *Walpole Island ecosystem recovery strategy*: The Walpole Island Ecosystem Recovery Strategy Team was established in 2001 to develop an ecosystem-based recovery strategy for the area containing the St. Clair River delta, with the goal of outlining steps to maintain or rehabilitate the ecosystem and species at risk (Walpole Island Heritage Centre 2002). Although the strategy is initially focusing on terrestrial ecosystems, there are future plans to include aquatic components of the ecosystem.

Conservation authorities continue to play a vital role in stewardship and public education programs that have resulted in increased awareness of species at risk, and improvements to habitat and water quality throughout the Wavyrayed Lampmussel range in Ontario.

6.2 Broad strategies

Four broad strategies for conservation measures, adapted from the original recovery strategy, are recommended to address threats to the species and its habitat as well as to meet the short-term management objectives: 1) Research and Monitoring; 2) Management and Coordination; 3) Stewardship; and, 4) Awareness. These broad strategies are further divided into numbered conservation measures with a priority ranking (high, medium, and low); identification of the threat(s) addressed; and, an associated timeline (Table 4).

6.3 Conservation measures

Success in the conservation of this species is dependent on the actions of many different jurisdictions; it requires the commitment and cooperation of the constituencies that will be involved in implementing the directions and measures set out in this Management Plan.

This Management Plan provides a description of the measures that provide the best chance of achieving the management objectives for the Wavyrayed Lampmussel, including measures to be taken to address threats to the species and monitor its management, to guide not only activities to be undertaken by Fisheries and Oceans Canada, but those for which other jurisdictions, organizations and individuals have a role to play. As new information becomes available, these measures and the priority of these measures may change. Fisheries and Oceans Canada strongly encourages all Canadians to participate in the conservation of the Wavyrayed Lampmussel through undertaking measures outlined in this Management Plan.

Table 4 summarizes those measures that are recommended to support the management objectives. The activities implemented by DFO will be subject to the availability of funding and other required resources. Although the Wavyrayed Lampmussel is only listed as a species of Special Concern, it coexists with other endangered and threatened mussel species within the aforementioned watersheds; therefore, it will receive the benefit of "high priority" implementation strategies that are being applied for such species. The majority of the conservation measures have been adapted from the original recovery strategy; however, several additional conservation measures that pertain to threats, mussel identification, instream barriers, stream flow and habitat maintenance/improvement are included (Table 4). More detailed narratives for some conservation measures are included after the table (Section 6.3).

Table 4. Conservation measures and implementation schedule

Number	Conservation Measure	Priority[2]	Threats or Concerns Addressed	Timeline
Broad Strategy – Research and Monitoring				
1-1	Research – field confirmation of host fish(es).	High	Host fish(es)	Ongoing
1-2	Monitoring populations – continue routine surveys to monitor changes in the distribution and abundance of all populations.	Medium	All threats	Ongoing
1-3	Monitoring habitat – use existing monitoring stations to track changes in Wavyrayed Lampmussel habitat.	Medium	All threats	Ongoing
1-4	Monitoring aquatic invasive species – continue to monitor reservoirs for establishment of Zebra Mussel, and track the upstream invasion of Round Goby in the Ausable, Sydenham, Thames, and Grand rivers.	Medium	Aquatic invasive species	Ongoing
1-5	Barrier analysis – assess the distribution of in-stream barriers in all basins. Determine their impact and the feasibility of barrier removal or mitigation where appropriate.	Medium	Altered flow regimes	Ongoing
1-6	Continue to investigate/test mitigation techniques for non-point source pollution and increasing levels of sodium chloride.	Medium	All threats	Ongoing
1-7	Investigate potential water quality issues resulting from stormwater management and wastewater treatment	Medium	Turbidity and sediment loading; contaminants and toxic substances; nutrient loading, altered flow	2018-2021

[2] Priority reflects the degree to which the action contributes directly to the conservation of the species or is an essential precursor to an action that contributes to the conservation of the species.

Number	Conservation Measure	Priority[2]	Threats or Concerns Addressed	Timeline
	facilities and encourage municipalities to upgrade their infrastructure to reduce such threats.		regimes; and habitat removal and alteration	
1-8	Identify contaminants and water quality parameters that could pose the greatest threat to the Wavyrayed Lampmussel.	Medium	Contaminants and toxic substances	2018-2021
Broad Strategy – Management and Coordination				
2-1	Promote and enhance expertise in freshwater mussel identification/biology and provide for the transfer of knowledge.	High	All threats	Ongoing
2-2	Collaborate between existing ecosystem recovery teams to implement conservation measures.	High	All threats	Ongoing
2-3	Ensure that flow requirements of the Wavyrayed Lampmussel are considered in management of flow regimes.	Medium	Altered flow regimes	Ongoing
2-4	Work with drainage supervisors, engineers and contractors to limit the effects of drainage activities on Wavyrayed Lampmussel habitat.	Low	Turbidity and sediment loading	Ongoing
Broad Strategy - Stewardship				
3-1	Ongoing implementation of agricultural best management practices and other habitat enhancement projects in the Ausable, Sydenham, Thames, and Grand rivers.	High	Turbidity and sediment loading, contaminants and toxic substances	Ongoing
3-2	Establish riparian buffer zones in areas of high erosion potential by encouraging naturalization or planting of native species.	High	Turbidity and sediment loading; contaminants and toxic substances; and nutrient loading	Ongoing
3-3	Limit livestock access to rivers.	High	Turbidity and sediment loading; contaminants and toxic substances; and nutrient loading	Ongoing
3-4	Encourage soil testing to	Medium	Contaminants and toxic	Ongoing

Number	Conservation Measure	Priority[2]	Threats or Concerns Addressed	Timeline
	determine fertilizer application rates.		substances and nutrient loading	
Broad Strategy - Awareness				
4-1	Conduct outreach through the various organizations in the Ausable River, Sydenham River, and Thames River watersheds.	Medium	All threats	Ongoing
4-2	DFO staff to continue to deliver presentations at conferences and to different naturalist groups and schools.	Medium	All threats	Ongoing
4-3	Increase public awareness of the potential impacts of transporting/releasing aquatic invasive species.	Medium	All threats	Ongoing
4-4	Increase awareness within the angling community about the role of the Smallmouth Bass as a host for the Wavyrayed Lampmussel.	Low	Host fish(es) (disruption); recreational activities	Ongoing
4-5	Continue to promote mussel identification and recognition through annual workshops and the use of the mobile mussel identification guide app for cellular phones.	Low	All threats	Ongoing

6.4 Narrative to support implementation schedule

1-1: The host species for Wavyrayed Lampmussel have already been confirmed in the lab. Field confirmation of host fish(es) is now required, which includes confirming that members of the host species occur in reaches at times when mature female mussels possess mature glochidia.

1-2 – 1-4: A network of monitoring stations has been established throughout the range of the Wavyrayed Lampmussel. Currently, there are established stations throughout the Sydenham River (Metcalfe-Smith and Zanatta 2003), the Thames River and Ausable River (T.J. Morris, DFO, unpubl. data), the Grand River (Baitz et al. 2008), and the St. Clair River Delta (Morris et al. 2005). Monitoring sites will permit:

- Quantitative tracking of changes in mussel abundance or demographics (size distribution, age structure etc.) or that of their host(s);
- Detailed analyses of habitat use and the ability to track changes in use or availability; and,

- The ability to detect the presence of aquatic invasive species (e.g., Zebra Mussel). Reservoirs represent the likely seed locations for Zebra Mussel in the inland rivers. Monitoring sites should be established within or close to these reservoirs to permit the early detection of Zebra Mussel in the event that it invades these systems. Monitoring of aquatic invasive species in the St. Clair River delta will likely be conducted in close association with the managed refuge sites.

Monitoring stations provide the opportunity to collect data on the distribution, demographics, habitat and hosts of all mussel species and will be incorporated into the recovery/management documents for other mussel species at risk.

1-5: An assessment of instream barriers should be conducted for all watersheds where the Wavyrayed Lampmussel is known to exist. Barriers should be mapped and their effects on local habitat conditions (e.g., flow, temperature, substrate stability and composition) should be assessed to determine if they are impacting Wavyrayed Lampmussel habitat. While instream barriers have been largely cited as having a detrimental effect on mussels through temperature and hydraulic changes as well as restricting host distributions, anecdotal evidence indicates that small barriers on the Sydenham River may be providing habitat for hosts of the Wavyrayed Lampmussel (M. Andreae, St. Clair Region Conservation Authority, pers. comm.).

1-8: Future research studies focusing on the effects of contaminants and fluctuations in water quality parameters, such as dissolved oxygen, are warranted to prioritize threats to the Wavyrayed Lampmussel.

2-1: The current capacity within southern Ontario to perform the necessary survey and monitoring work is insufficient. Knowledge of freshwater mussel identification, distribution, life history and genetics is limited to a small number of individuals from a limited number of government and academic institutions. A concerted effort must be made to increase this capacity by:

- Training personnel in the identification of all mussel species with emphasis on the rare species; and,
- Encouraging graduate and post-graduate research aimed at fulfilling the needs identified under Research and Monitoring.

2-2: Many of the threats to the Wavyrayed Lampmussel can be classified as widespread and chronic (see section 4.2 Threats) and represent general ecosystem threats affecting numerous other aquatic species. Efforts to remediate these threats will benefit many species in addition to the Wavyrayed Lampmussel and should be implemented in close connection with the aquatic ecosystem recovery teams for the Thames, Grand, and Sydenham rivers (see section 6.1 Actions already completed or currently underway) to eliminate duplication of efforts and ensure that undertaken activities are not detrimental to other species.

2-3: The Wavyrayed Lampmussel is a species adapted to hydrologically stable flow regimes and does not possess any of the shell modifications typical of species adapted to high shear environments (Watters 1994). The species has also been identified by Tetzloff (2001) as one of the most susceptible species to low dissolved oxygen conditions, which may be associated with toxic events or reductions in flow conditions (Johnson et al. 2001). Careful consideration must be paid to the management of flow regimes in rivers with Wavyrayed Lampmussels to ensure that flow conditions remain within preferred levels for this species.

2-4: Drainage development and maintenance activities that mitigate existing threats and prevent the continued degradation of aquatic habitat within the range of the Wavyrayed Lampmussel should be supported and promoted.

3-1 – 3-4: The activities characterized in this section, and represented by the sample of activities above, embody sound agricultural practices that, when implemented, will benefit both the terrestrial and aquatic ecosystems. These activities can generally be referred to as “best management practices”. In the three watersheds with aquatic ecosystem recovery strategies (Ausable, Sydenham, Thames), as well as the two watersheds with other recovery plans (Grand River, Lake St. Clair), it will be important for members of the Ontario Freshwater Mussel Recovery Team (OFMRT) to interact closely with members of these teams when carrying out conservation measures for the Wavyrayed Lampmussel. Many of the ecosystem teams will have established stewardship liaisons and have activities already underway that will complement the conservation measures benefiting the Wavyrayed Lampmussel.

4-4: The likely host of the Wavyrayed Lampmussel, the Smallmouth Bass, is a popular sport-fish in southern Ontario and may necessitate an outreach program with the sport-fish industry in watersheds where impacts have been confirmed. Outreach activities should be focused on ensuring a non-destructive sport-fishery directed at locations and times when Smallmouth Bass are unlikely to be harbouring Wavyrayed Lampmussel glochidia. This will be particularly important in the Sydenham River.

4-5: Increased basic mussel knowledge and identification skills can be assisted through the awareness materials identified here including the *Photo Field Guide to the Freshwater Mussels of Ontario* (Metcalfe-Smith et al. 2005), the annual hands-on mussel identification workshop offered by DFO to government, agency, non-government organizations, Aboriginal peoples, and the public, and the recently completed identification “app” - *Canadian Freshwater Mussel Guide* now available for free download from the Apple app store.

7. Measuring progress

Reporting on implementation of the Management Plan under s. 72 of SARA will be done by assessing progress towards implementing the broad strategies and conservation measures. The implementation of this Management Plan will be monitored within five years after the plan has been posted to the Species at Risk Public Registry.

8. References

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Appendix A: Effects on the environment and other species

A strategic environmental assessment (SEA) is conducted on all SARA recovery planning documents, in accordance with the Cabinet Directive on the Environmental Assessment of Policy, Plan and Program Proposals. The purpose of a SEA is to incorporate environmental considerations into the development of public policies, plans, and program proposals to support environmentally sound decision-making.

Management planning is intended to benefit species at risk and biodiversity in general. However, it is recognized that the implementation of management plans may also inadvertently lead to environmental effects beyond the intended benefits. The planning process based on national guidelines directly incorporates consideration of all environmental effects, with a particular focus on possible impacts upon non-target species or habitats. The results of the SEA are incorporated directly into the plan itself, but are also summarized below.

The Wavyrayed Lampmussel is a sensitive species, particularly to issues of water clarity and quality. For this reason, it is expected that efforts made to improve conditions for the Wavyrayed Lampmussel will benefit most other aquatic species. A few opportunistic species that can readily adapt to degraded conditions (e.g., Giant Floater [*Pyganodon grandis*] or Fathead Minnow [*Pimephales promelas*]) may see a decline in numbers/range as a result of rehabilitative efforts. These changes should not be viewed in a negative light but rather as a resetting of the aquatic community to pre-disturbance conditions.

This Management Plan will clearly benefit the environment by promoting the conservation of the Wavyrayed Lampmussel. The potential for the plan to inadvertently lead to adverse effects on other species was considered. The SEA concluded that this plan will have a positive effect on the environment and will not entail any significant adverse effects. The reader should refer to the following sections of the document in particular: species' description, habitat and biological needs, ecological role and limiting factors, and conservation measures.